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STUDIES OF THE GASTRIC RESIDUUM

I. A STUDY OF EIGHTY SAMPLES OF GASTRIC RESIDUUMS OBTAINED FROM APPARENTLY NORMAL WOMEN *

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Extensive studies of the gastric residuum of normal men have been made by Hawk and collaborators.[1] These investigations have demonstrated that the average volume is quite large (in over 100 normal cases the average was 52.14 c.c.), quite contrary to the views of Loeper,[2] Zweig,[3] Kemp,[4] Wolff,[5] Strauss,[6] Riegel,[6] and Soupalt,[6] who assert that the quantity of residuum in the normal fasting stomach should not exceed 20 c.c. Rosin and Schreiber[6] suggest a maximum limit of 60 c.c. for the volume of the gastric residuum. A variation of from 17 to 180 c.c. in the volumes of the various residuums examined by Hawk further demonstrates the unimportance of the quantity of residuum as an aid in diagnosis. These findings of Hawk and collaborators have recently been confirmed by Talbot.[7]

The residuum is a physiologically active secretion[8] and is probably in part the result of the activity of the gastric glands[8] and in part the result of fluid which passes by osmosis[8] through the stomach walls into the lumen of the stomach. The fact that bile and trypsin are both quite frequently found in the residuum leads one to believe that a portion of it at least is due to regurgitation of fluid from the duodenum.[9] Swallowed saliva and esophageal secretions may also give rise to another portion.[10] The last factor was greatly eliminated in the work of Hawk and collaborators[1] by encouraging the subjects to reject as much saliva as possible by expectoration. That the residuum is not wholly due to saliva was clearly demonstrated by Fowler, Rehfuss and Hawk, in the case of Subject B 106 a. This subject, normal in every way, submitted to the passage of the tube on the empty stomach in the morning. Forty-nine c.c. of liquid were removed, and tests showed that the stomach was empty. Two hours later, during which time the person in question attended a lecture, was free from psychic stimuli, and swallowed no saliva, 29 c.c. were withdrawn (Case B 106 b). Furthermore, these two secretions were essentially the same in every particular. Carlson[11] has also demonstrated that a fluid is being continuously secreted into the empty stomach.

The total and free acidities are subject to almost as wide variations as is the volume. The total acidity, in the cases presented by Hawk, ranged from a minimum of 2.4 c.c. of tenth-normal sodium hydroxid to titrate 100 c.c. of juice (about 0.009 per cent. acidity in terms of hydrochloric acid) to a maximum of 77.6 c.c. (about 0.28 per cent. hydrochloric acid), with a mean average of 29.9 c.c. (about 0.11 per cent. hydrochloric acid). The free acidity averaged 18.5 c.c. (about 0.07 per cent. hydrochloric acid), with a range from 0 c.c. (0 per cent. hydrochloric acid) to 65.8 c.c. (about 0.24 per cent. hydrochloric acid). These acidities are much smaller than those given by Carlson,[12] and obtained from a subject with a gastric fistula. The acidities of the contents of the empty stomach of this subject were 0.23 per cent. hydrochloric acid and 0.18 per cent. hydrochloric acid for total and free, respectively.

A definite relation between the pepsin content of the gastric residuum and total acidity has been demonstrated for low acid values, but this relation has been shown to disappear as high acid values are approached (Fowler, Rehfuss and Hawk).[1]

The same investigators found trypsin to be present in practically every specimen of residuum which was examined for it. Dorner[13] showed the presence of trypsin in practically all of the residuums obtained from 154 patients, most of whom had gastro-intestinal disturbances. The cases reported by Hawk and co-workers[1] were nonpathologic. The occurrence of trypsin in the stomach has been more completely studied by Spencer, Meyer, Rehfuss and Hawk.[9]

The present investigation was undertaken for the purpose of determining whether or not there existed any pronounced differences between the residuums of normal men, and the residuums of normal women.

METHODS

The subjects of the experiments described in this paper were young women students in the courses in physiologic chemistry at Iowa State College. They willingly submitted themselves for the experimental work, and were requested to drink no water at any time after their evening meal on the night previous to the experiment. They came for the removal of the residuum at 8 o'clock the following morning, and every residuum was removed as near that time as was compatible with the experiment. Each woman was given a thorough examination, physically and by questioning, to detect any abnormalities if they existed.

The residuums were removed by means of a modified stomach tube described by Rehfuss.[14] The swallowing of the tube was accomplished without the aid of water. The tube and tip were first coated with a thin film of petrolatum, and then the tip was placed in the lower part of the pharynx, back of the tongue, and swallowed without much difficulty. When the tube had reached the stomach (which was ascertained by measurements), the contents were aspirated from it while the subject was reclining on her back, stomach and on each side and breathing deeply. The liquid was immediately measured, placed in an Erlenmeyer flask, and its characteristics noted. The residuum

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* Because of lack of space, this article is abbreviated in THE JOURNAL by omission of a table of tests of the normal gastric residuum of women. The complete article appears in the reprints, a copy of which will be sent by the authors on request.

1. Rehfuss, M. E.; Bergeim, Olaf, and Hawk, P. B.: Gastro-Intestinal Studies, I, The Question of the Residuum Found in the Empty Stomach, THE JOURNAL A. M. A., July 4, 1914, p. 11. Fowler, C. C.; Rehfuss, M. E., and Hawk, P. B.: Gastro-Intestinal Studies, X, An Investigation of the Gastric Residuum in Over One Hundred Normal Cases, Sept. 18, 1915, p. 1021.
2. Loeper; Leçons de pathologie digestive, Series 2, 1912, pp. 17-19.
3. Zweig: Magen und Darmkrankheiten, p. 459.
4. Kemp: Diseases of the Stomach, Intestine and Pancreas, 1912, p. 133.
5. Wolff: Taschenbuch der Magen und Darmkrankheiten, p. 22.
6. Cited by Loeper (Footnote 2).
7. Talbot, E. S., Jr.: The Examination of Normal Gastric Secretion by the Fractional Method, THE JOURNAL A. M. A., June 10, 1916, p. 1849.
8. Fowler, Rehfuss and Hawk (Footnote 1).
9. Fowler, Rehfuss and Hawk (Footnote 1). Spencer, Meyer, Rehfuss and Hawk: Am. Jour. Physiol., 1916, **39**, 459. Boldyreff: Quart. Jour. Exper. Med., 1914, **8**, 1.
10. Sokolow: Dissertation, St. Petersburg, 1904 (Babkin: Die Aeussere Sekretion der Verdauungsdrusen, 1914, p. 110). Grobbel: Ztschr. f. physiol. Chem., 1914, **89**, 1.
11. Carlson: Am. Jour. Physiol., 1913, **31**, 151.
12. Carlson: Am. Jour. Physiol., 1915, **38**, 248.
13. Dorner: Deutsch. Arch. f. klin. Med., 1915, **117**, 540.
14. Rehfuss: Am. Jour. Med. Sc., June, 1914.

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was then filtered through moistened qualitative filter papers, and the first few drops of filtrate were discarded. The following determinations were then made, as far as possible, on the filtered residuum: total acidity, free acidity, pepsin and trypsin.

The methods[15] for total acid, free acid and pepsin were those used by Rehfuss, Bergeim and Hawk.[16] Trypsin was determined by the method of Spencer.[17]

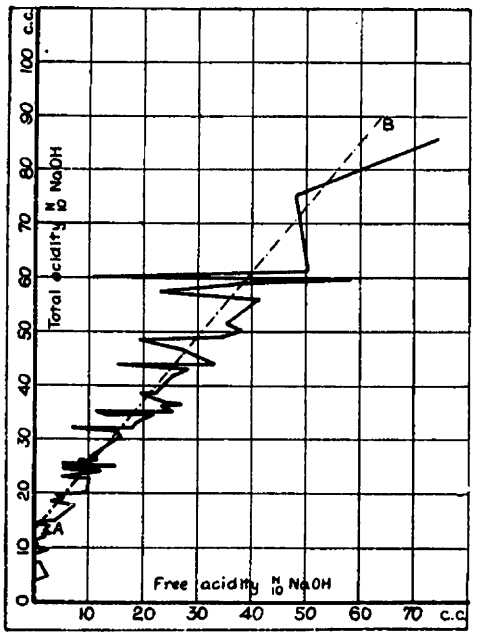

Chart 1.—Relation of total to free acidity of residuums.

DATA

Eighty-one samples of residuums were collected from sixty different subjects; twenty-one of the subjects submitted to the passage of the tube twice.

Averages on the Compilation of the Normal Gastric Residuum.—1. The average quantity removed in eighty-one cases was 49.44 c.c., the largest quantity being 135 c.c. and the smallest 12 c.c.

2. In sixty-nine cases noted, the residuum was in twenty-two cases (32 per cent.) colorless, and in forty-seven cases (68.1 per cent.) yellow or green.

3. The total acidity recorded in eighty-one instances averaged 30.3 in terms of tenth-normal sodium hydroxid, with the highest figure at 86.0 and the lowest at 4.0.

4. The free acid (seventy-nine cases) averaged 15.6, with figures ranging from 74.5 to 0.

5. The pepsin concentration as measured by the Mette method was determined in seventy-nine cases, and gave an average[18] of $(3.3)^2$, highest $(6.7)^2$ and lowest $(0.0)^2$.

6. Trypsin was tested for in sixty-three cases, with an average of 5.2 units; ten cases gave 16 units, and fifteen no reaction. Thus in 23.8 per cent. of the cases there was no evidence of trypsin.

7. Microscopic examination revealed on no occasion gross food residues. On several occasions vegetable débris was found, but never meat fibers. Leukocytes, in considerable number, were found almost constantly, and occasionally swallowed material from the throat with bacteria.

COMMENT

In eighty-one cases the average volume of the gastric residuum of normal women was 49.44 c.c. This quantity is greatly in excess of the generally accepted limit of 20 c.c., and very close to the average value of 52.14 c.c. obtained from over 100 cases of normal men.[8] The range of volumes was likewise extremely wide (from 12 to 135 c.c.), similar to the range of from 23 to 160 c.c. obtained by Fowler, Rehfuss and Hawk.[1] Hence in regard to volume there appears to be little or no variation in the residuums of normal men and normal women. The volumes of the residuums obtained from women were only slightly lower than those obtained from men.

Decided variations in the color of the residuums of normal women were observed (similar to variations observed in the case of men);[8] 31.9 per cent. of the observed cases were colorless, while 68.1 per cent. were colored. This shows a slightly lower percentage of colorless samples and a slightly higher percentage of colored samples in the case of women than in the case of men (men 43 per cent. colorless, 56 per cent. colored).[8] Both colorless and bile colored residuums were obtained from the same individual at different times, and even were occasionally obtained during the course of a single aspiration. This was especially noticeable after the subject had rolled from one side to the other. The color is apparently controlled by the flow of bile through the pylorus into the stomach, rather than as Sartory[19] has suggested by the growth of a chromogenic yeast (*Cryptococcus salmoneus*). This point is being made the subject of an extended experiment in this laboratory and will be reported on in a later paper.[20]

The color is more often seen in cases of high acidity. Of the forty-seven colored cases reported, about 85 per cent. appear in acidities over 30, while only 15 per cent. appear in acidities of less than 30. This would appear further to support Boldyreff's[9] idea of duodenal regurgitation to regulate gastric acidity.

The relation of total acidity to free acidity is shown by Chart 1. As in the instance of the previously cited cases of men, free acidity is rarely encountered until the total acidity exceeds 10. In total acidities of over 14 there were no cases in which free acidity was not demonstrable (over 13.5 found by Fowler, Rehfuss and Hawk[1] for men). The greater number of the residuums lie between total acidities of 20 and 60

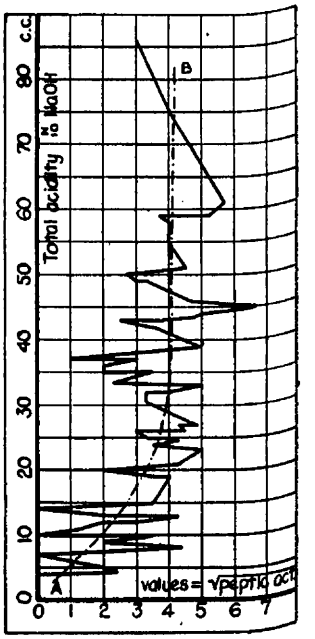

Chart 2. — Relation of pepsin content to total acidity of the residuums.

15. Hawk: Practical Physiological Chemistry, Ed. 5, pp. 162, 165, 166.
16. Rehfuss, M. E.; Bergeim, Olaf, and Hawk, P. B.: Gastro-Intestinal Studies, II, The Fractional Study of Gastric Digestion, with a Description of Normal and Pathologic Curves, THE JOURNAL A. M. A., Sept. 12, 1914, p. 909.
17. Spencer: Jour. Biol. Chem., May, 1915.
18. In this paragraph, the superior 2 (^{2}) indicates the square of the preceding quantity.
19. Sartory: Bull. Soc. de biol., 1906.
20. Fowler, Levine and More: Unpublished data.

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(from 25 to 52 for men).[8] A few lie above 60, and considerably more below 20. The average total acidity was 30.3, and the average free acidity was 15.6 (the average acidities in the case of men were: total, 29.9; free, 18.5).[8] The range in total acidity for women was found to lie somewhat higher (from 86.0 to 4.0) than it was found to lie for men (from 77.6 to 2.4),[8]

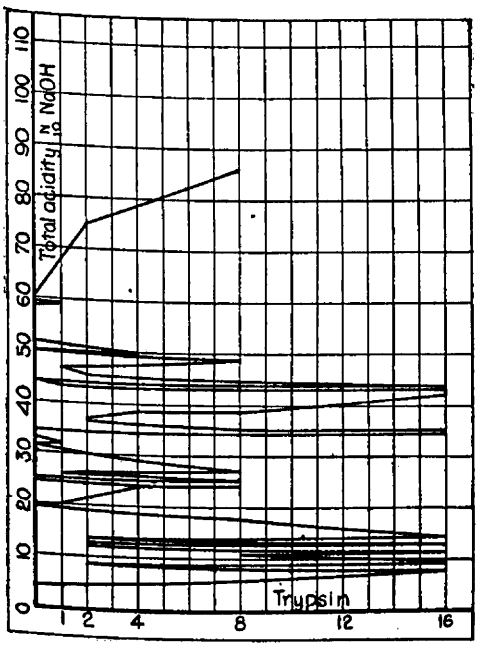

Chart 3.—Relation of trypsin to total acidity of residuums.

and the same was true for free acidity, women, (from 74.5 to 0); men, (from 65.8 to 0).[8] Only two cases were above 70 in total acidity.

In regard to acidities, and also volumes, it is worth mentioning that we have noticed at various times during our investigation a remarkable constancy in the volume and total acidity of residuums from the same person collected at widely different times. This point is worth further investigation.

Pepsin was tested for in every case studied but two, and was found in all cases tested, except three of low acidity. The average value[18] of peptic activity was $(3.3)^2$, somewhat higher than the value of $(2.8)^2$ obtained for men.[8] The highest value was $(6.7)^2$, compared to $(5.0)^2$ for men,[8] and the lowest were $(0.0)^2$, men[8] $(0.7)^2$.

In the case of women the same relationship between the quantity of pepsin and total acidity for low acid values is seen (Chart 2) as was observed in the case of men.[8] This view is contrary to that of Pawlow,[21] who asserts that no such relation exists. This relationship is likewise seen to disappear as high acid values are reached, more or less supporting the view of Gregersen[22] who states that the relation of pepsin to hydrochloric acid is not an absolute one. In none of our cases were we able to demonstrate the presence of pepsin in the absence of total acidity. Aliprandi[23] asserts that pepsin may occur in the absence of hydrochloric acid, and also that there is no strict parallelism between pepsin and hydrochloric acid.

The trypsin content of the gastric residuum of women was determined in sixty-three cases. Our results do not bear the striking similarity to the trypsin content of the gastric residuum of men[8] (only twenty-six cases determined) that the volumes, total acidities, free acidities and pepins do. Charts 3 and 4 show the relation of trypsin to total and free acidity, respectively. From these charts the relation of trypsin to free acidity is not as evident as it was in the work on men.[8] Furthermore, several cases of low acidity were obtained in which there was no trypsin or only a little, while one case, the acidity of which was over 70, presented a trypsin content of 8. In the case of men,[8] a content of trypsin equivalent to 16 was not found above a free acidity of 20; several were found between 20 and 30 in the case of women. Of the sixty-three cases examined, fifteen, or 23.8 per cent., contained no trypsin as compared to 7.7 per cent. in the case of men.[8] An average value of 5.2 units was obtained for trypsin in the cases of women, as compared to 9.1 units for men.[8] This and the previously mentioned differences may constitute a fundamental difference between the residuums of men and women; but we are inclined, for the present at least, to consider these differences to be due mainly to the smaller numbers of cases examined in the work of Fowler, Rehfuss and Hawk.[1] This can be settled only by a more extensive investigation.

SUMMARY

1. No striking differences between the gastric residuums of normal women and of normal men have become evident during the course of this investigation.

2. The accepted limit of 20 c.c. for the volume of the residuum of the empty stomach of normal women is too low. An average volume of 49.44 c.c. was obtained in eighty-one cases.

3. Both colorless and bile-colored residuums may be found. The two may occur in the same individual on different days or during the same aspiration.

4. The colored residuums are found more frequently in higher acidities. This is explained, as before, by the greater frequency of regurgitation in higher acidities.

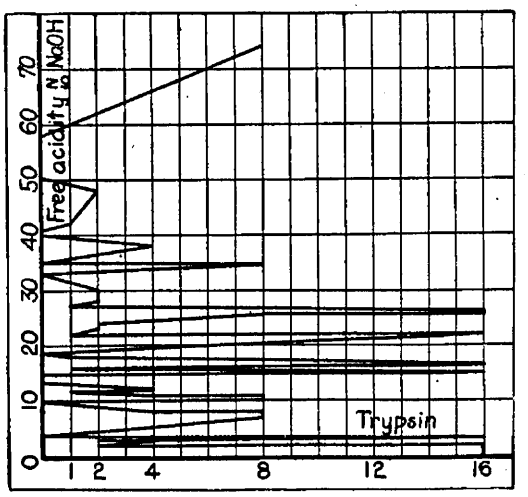

Chart 4.—Relation of trypsin to free acidity of residuums

5. Total and free acidity vary directly with each other, free acidity rarely being found with a total acidity of less than 10, and always being found when the total acidity was greater than 14.

6. Two cases were observed in which the total acidity was greater than 70. In general, the total and free acidities of the residuums of the women subjects

21. Pawlow: The Work of the Digestive Glands.
22. Gregersen: Arch. f. Verdauungskr., **19**, 263.
23. Aliprandi: Lavor. riv. chem. micros. clin., **1**, 230.

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observed run higher than those of the men subjects reported by Fowler, Rehfuss and Hawk.[1]

7. The definite relation of pepsin to acid in low acid concentrations has been confirmed. Also, this relation is seen to disappear as high acid values are approached.

8. The trypsin content of the gastric residuums obtained from women was shown not to bear the striking inverse relation to the free acidity that was demonstrated to be true in the case of residuums obtained from men.[8] This is thought to be due to the larger number of samples examined in the present investigation, and not to be due to any fundamental difference in the residuums of men and of women.

ABSOLUTE DIABETES WITH RETURN OF FUNCTION

REPORT OF A CASE *

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CLEVELAND

By an absolute diabetes is meant one in which the patient so afflicted is not able to utilize any carbohydrate which is taken in the food or any of the sugar which is yielded from protein metabolism. There is no very good evidence that fat is converted to sugar in the diabetic. All diabetics of the severity of this case, it is reasonable to assume, have no deposits of glycogen in their tissues. The only two sources for sugar, then, would be that which was fed to the patient and that derived from the breaking down of the protein molecule. Each 6.25 gm. of protein which is utilized in the body is represented by 1 gm. of nitrogen excretion. Practically all nitrogen is eliminated through the kidneys. Since fats are not converted to sugar, and since there are no glycogen deposits in the tissues, it is readily apparent that any sugar which is excreted in the urine of a starving diabetic must come from the protein. If the total nitrogen output and the total sugar output are determined for twenty-four hours and the former divided into the latter, it will give the ratio of dextrose to nitrogen excretion or the amount of sugar which is derived from the utilization of 6.25 gm. of protein. We know experimentally that each 6.25 gm. of protein taken into the body will yield 3.65 gm. of sugar; therefore a patient who is excreting 3.65 gm. of sugar for each gram of nitrogen in the urine is an absolute diabetic, or cannot utilize the sugar which is derived from the body protein.

A dextrose to nitrogen ratio of 3.65:1 occurring in diabetics was termed the "fatal ratio" by Lusk.[1] Certainly a better terminology could not have been given the condition. Practically all of the patients who have been reported who have shown this "fatal ratio," have died. Greenwald,[2] Foster,[3] Geyelin and Du Bois[4] have reported cases in which there has been subsequent return of sugar tolerance. In none of the three cases just cited was starvation employed during the entire course of the high dextrose to nitrogen excretion. In the case I am describing, starvation was practically continuously adhered to from the time it was started, until the patient became sugar free. I feel confident starvation was the factor which shortened the course of the "fatal ratio" period in this case, and without its aid our patient would doubtless have succumbed to his severe diabetes combined with the infection which he had with acidosis. After a brief critical period of four days, the patient was free from all severe diabetic symptoms. The starvation was not a hardship for him. Besides, from fear of the danger of starvation, he never complained after the second day of the prolonged fasting.

REPORT OF CASE

History.—D. M., man, aged 26, white, carpenter, was first admitted to Lakeside Hospital, April 8, 1915, and was discharged three weeks later. His complaint at that time was extreme weakness and dull aching pain across the lower portion of his back. There was no history of any other member of his family having been afflicted with diabetes. The past history was negative aside from measles when a child. The present trouble dates back to April, 1913. While engaged in some light work the patient suddenly became very weak and was unable to continue. He immediately went to see a doctor who told him he had sugar in the urine. He remained away from his work for a short time and was cautious with the food he ate; he immediately felt much improved and resumed his regular duties. For six months he remained comfortable. He then commenced to have excessive thirst, increased urine output, persisting weakness and gradual loss in weight. Since that time his condition had been variable; some days he felt good and other days he was totally incapacitated, depending on how closely he adhered to his diet. During the last three months, the patient had been having numerous boils and pains in his back and legs.

Physical Examination.—The patient impresses one as not possessing average mentality; he talks at random and asks countless questions during the day. He is a well developed man but extremely poorly nourished. His weight prior to the onset of this trouble was 156 pounds; he now weighs 125 pounds. He is extremely weak and prefers to lie on the bed. His actions and movements are those of a senile man. There is a very marked sweetish odor to the patient. Skin and mucous membranes are dry and parched. There is a bright scarlet hue to the skin about the face and neck; he looks as if he were sunburned, but has not been exposed to the sun. Nothing abnormal was observed from an examination of the eyes and eye grounds or the nose and ears. The teeth are in moderately good condition, but there is a marked pyorrhea alveolaris. The tonsils are small and show no signs of infection. Heart, lungs and abdomen are normal. Reflexes are slow and sluggish in response, but there are no other abnormal findings from the neurologic examination.

The Wassermann reaction is negative on blood and spinal fluid.

Urine examination shows 97 gm. of sugar in the twenty-four hours. The acetone and diacetic reactions are very distinct.

During the patient's stay of three weeks in the hospital it was not possible to get his sugar output below 45 gm. in the twenty-four hours by strict dieting. He was feeling much better, however, and insisted on going home, so he was discharged.

During the time from his first admission to the last one with which we are interested, nothing more was heard of the patient until he presented himself to our dispensary, Jan. 14, 1916. He was promptly admitted to the hospital.

Record of Last Admission.—D. M. was admitted to the medical service for the second time, Jan. 14, 1916. His complaint at this time was a severe cold and a boil on the back of his neck, both of which developed about one week before. Since his discharge from the hospital, April 21, 1915, his condition had been variable; a part of the time he was able to work. He volunteered the information that his diabetes was better and his only trouble was the cold and boil.

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* From the Department of Medicine and the Laboratory for Medical Research of Lakeside Hospital and Western Reserve University School of Medicine.

1. Mandel, A. R., and Lusk, Graham: Diabetes Mellitus, THE JOURNAL A. M. A., July 23, 1904, p. 241.
2. Greenwald: Jour. Biol. Chem., 1913, **16**, 393.
3. Foster: Deutsch. Arch. f. klin. Med., 1913, **110**, 501.
4. Geyelin, H. R., and Du Bois, F.: A Case of Diabetes of Maximum Severity with Marked Improvement, THE JOURNAL A. M. A., May 13, 1916, p. 1532.

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